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Fairy Rings: Toadstools, Stinkhorns, and Puffballs

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Before the germ theory of disease was accepted by science, supernatural explanations for plant diseases prevailed throughout the world. The wills of gods, demigods, sprites, witches, and devils were believed to determine what befell man's crops on the Earth. Even highly developed civilizations such as the ancient Roman Empire engaged in annual sacrificial rites to pay homage to the god of rust diseases, Robigus, so that calamitous crop failures could be averted by appeasement.

Many societies had legends pertaining to the overnight appearance of arcs or circular rings of mushrooms. These they dubbed "fairy rings" for their presumed link to supernatural beings. Fairy rings, according to legend, are a cause or a result of supernatural phenomena. For example, in Holland the ring was thought to be where the Devil churns butter. To intentionally enter a fairy ring in France was believed to bring forth large toads upon the trespasser. In England it is considered good luck to build a house on a fairy ring site. Certainly, the rapid appearance of mushrooms in a landscape, particularly in a pattern that appears to be deliberate, seems magical to those who do not understand fungi.

Contemporary science treats fairy rings not as products of supernatural beings or events but as plant diseases caused by basidiomycete fungi. The unsightly, pathogenic green rings damage the aesthetic and utilitarian value of residential and recreational turfgrasses. They are unacceptable and potentially damaging blemishes in high-value turf settings and a nuisance to homeowners. The dead and dying, hydrophobic "dry spots" and the appearance of mushrooms pose a particular problem for resort landscapes and golf course fairways, tees, and greens. Acres of contiguous turfgrass can become permeated with unsightly and costly rings as the causal fungi are spread around the area during normal turf use and maintenance. All commonly cultivated turfgrasses can be hosts of these fungal pathogens.

Fairy rings may be among the world's oldest living organisms. According to the British researcher Dickinson (1979), the radial growth rate of grassland fairy rings has been measured at between 4 and 14 inches (99 and 350 mm) per year. Because ring diameters up to hundreds of meters were recorded, it was surmised that some rings might be as old as 600–700 years.

In contemporary Hawai'i, fairy rings are sometimes called Menehune rings, after the legendary race of small people believed to work secretly at night to build things.

This publication describes fairy rings and what can be done to prevent, control, and eradicate them.

Fairy ring symptoms and signs

Besides the occasional appearance of mushrooms above ground, fairy ring fungi cause bands of turfgrass, darker green and more quickly growing than adjacent grass plants of the same species, occurring in arcs or circles. These "stimulated zones" of grass may range in width from several inches to about a foot. Rings tend to occur together in the same area. Rings may overlap, creating scalloped edges where the leading edges of adjacent rings exterminate one another. The diameter of these rings can be from a few feet to 60 feet or more.

When soil moisture is high, fungal fruiting bodies of the pathogen may grow in and along the circular band of stimulated grass. Common names for these sporophores include mushrooms, toadstools, and puffballs. They can be abundant and can form a continuous circle throughout the circumference of the rings.

The underground body of a fairy ring fungus consists of a network of filaments, the mycelium. It grows outward

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A partial fairy ring (above, left) in a residential lawn in Holualoa, Hawai'i. The mushroom, a poisonous species (*Chlorophyllum molybdites*, the green-spored parasol mushroom, above right), appeared after several days of heavy rainfall. The green outer band of lush turf normally coincides with a ring of toadstools. Photos: S. Nelson

radially as it decomposes and feeds upon organic matter in the soil. Behind the advancing fungus front, the mass of mycelium dies. The dead mycelium forms a dense and water-repellant mat that causes grass to die from drought stress. The green ring develops as the fungus grows through the soil and thatch, decomposing organic matter. This decomposition of organic matter releases ammonium. Other microorganisms reduce the ammonium to nitrate, and the nitrate stimulates lush growth of turf ahead of the leading edge of the fairy ring.

Some other turf diseases create ring patterns in turf, but they are not caused by basidiomycetes and they are not classified as fairy rings.

The pathogens

Fairy-ring pathogens are basiodiomycetes, fungi that produce their sexual spores (basidiospores) on a club-shaped spore-bearing structure (basidium). Most basidiomycetes are fleshy fungi (i.e., mushrooms, puffballs, stinkhorns, conks) involved in organic matter decay or as pathogens causing root and stem rots of plants.

More than 50 species of basidiomycete fungi cause fairy rings. Some species are edible, and some are deadly poisonous. Genera of basidiomycetes associated with fairy rings include *Agaricus, Agrocybe, Amanita, Boletus, Bovistra, Calvatia, Cantherellus, Chlorophyllum, Clitocybe, Collybia, Cortinarius, Disciseda, Hebeloma, Hydnum, Hygrophorus, Lactarius, Lepiota, Lycoperdon, Marasmius, Paxillus, Scleroderma, Tricholoma*, and *Vascellum*. Fairy ring fungi occur throughout the world, including most areas of Hawai'i.

The fleshy-fungi basidiomycetes exist saprophytically on decaying organic matter, while some species also have a parasitic phase on higher plants, causing root rots and stem rots of trees. Some non-fleshy species of basidiomycete fungi, the rusts and the smuts, cause devastating plant diseases worldwide.

Two types of disease manifestations are of concern with fairy rings. Grass plants either green up unacceptably due to excess nitrate availability, or the plants wither and die from drought stress brought about by fungus-induced soil hydrophobicity.

Basidiomycete life cycle

Small, green rings appear as the initial symptom of the infection. The rings become progressively larger over time and the fungus grows radially in the thatch and/or the soil. The rings can increase in size up to about 20 inches annually and can become quite large after years of infection have ensued.

The fairy ring fungus remains in a mycelial, vegetative growth mode most of the time, and this is how its body expands in the soil or turf thatch. The mycelium explores the soil depths and also spreads laterally, breaking down organic matter and absorbing nutrients. Sexual reproduction and sporophore production occur only during favor-

ing environments, usually wet weather. The mushrooms, or other types of sporophores, appear in Hawai'i in lawns or landscapes after at least several days of rain, or at any time after frequent and thorough watering on golf courses or other sports or residential turfs. After a week or more of continuous rainfall, fairy rings become a common sight in landscapes throughout Hawai'i. The fruiting fungal bodies bear tiny basidiospores for long-distance dispersal by wind, water, or through incidental contact with and transport by a vector. Eventually some of these spores create new infestations in turfgrass elsewhere, renewing the disease and life cycles.

For illustrated introductory information about basidiomycete life cycles and the life cycles of mushrooms, visit the websites of Dr. George Wong (UH Mānoa, Botany) cited under *References*.

Disease cycle summary

Dissemination. Basidiospores or mycelial fragments are dispersed by wind, water, soil, vectors (humans, some insects, snails, and slugs), seeds, or on tools and equipment.

Infestation. Basidiospores or mycelial fragments are deposited in thatch or soil containing the appropriate type of organic matter for a food supply (decaying wood or grass clippings).

Infection and pathogen development. The basidiospore(s) or hyphal fragment(s) germinate within the thatch or soil and begin to grow outward in all directions. The fungus withdraws nutrients from the organic matter in the soil. The fungal mycelium spreads throughout the thatch or soil layer, up to 12 inches deep in some soils.

Symptom and disease development. The first evidence of infestation is the presence of a cluster of mushrooms or a band or tuft of dark green grass. The ring or band of green grass results from the nitrogen that becomes available as the fungus decomposes the organic matter in the thatch or soil. A central area or spot or ring of dead grass may develop, caused by a loss of soil moisture from the area of fungal concentration. In the hydrophobic layer of dead grass and contaminated soil is a thick growth of fungal mycelium.

Reproduction. Sexual reproduction occurs and mushrooms or other sporophores form at the periphery of the rings during periods of favorable conditions (rainy weather or intensive irrigation). The basidiospores are borne in the gills of mushrooms.

Survival. The fungi survive as spores and mycelial fragments in or on organic debris, and as pathogens of woody plants (roots, stems).

Predisposing factors:

- warm weather and moist or wet soils, followed by very dry periods
- buried wood in the landscape (tree logs, limbs, roots, construction lumber, etc)
- stressed or under-nourished turf
- excessive irrigation
- heavy or unmanaged thatch
- poor soil aeration
- inadequate or poor soil layer beneath the turf.

Integrated pest management practices (IPM) for fairy rings

It is important to identify the fungus associated with a fairy ring to genus level in order to achieve the best control, because the available fungicides may vary in their ability to suppress certain species. Accurate identification can only be done by collecting the sporophores of the pathogen.

Avoidance

- When building a golf course or installing new turf, ensure that no buried lumber or wood remains in the soil, such as tree stumps and roots. Do not use bulldozed trees as fill materials in the landscape.
- Use caution when treating existing fairy rings not to move infested soil to new locations.
- Minimize plant stress; this may mean raising the mowing height on fairways, tee boxes or greens while treating fairy rings.
- Maintain optimum growing conditions for turfgrass with proper irrigation, thatch control, and fertility.
- Use a vertical mower to remove thatch, followed by topdressing.
- Remove tree stumps and roots from existing turf installations.
- Avoid excessive applications of irrigation water and fertilizers, because these practices favor the formation and growth of fairy rings.
- Fungicide applications used as a preventive measure may help.

Suppression

Suppress mycelial growth with fungicides applied either

Some fungicides for sale in Hawai'i for control of fairy rings in turfgrasses*

*Product name***	*Active ingredient*	*Formulation*
Bayleton (various products)	Triadimephon (50%)	Wettable powder
Disarm 480 SC	*1	Flowable concentrate
Endorse (various products)	Polyoxin D zinc salt (2.5%)	Wettable powder
Headway	Propiconazole (9.45%); Azoxystrobin (5.73%)	Emulsifiable concentrate
Heritage TL	Azoxystrobin (8.8%)	Emulsifiable concentrate
Heritage	Azoxystrobin (50%)	Water dispersible granules
ProStar 70WP	Flutolanil (70%)	Wettable powder

*soil sterilants methyl bromide and metam-sodium are also available for certain applications
**arbitrarily selected product names, others may be available.
*1. Methanone, [2-[[6-(2-chlorophenoxy)-5-fluoro-4-pyrimidinyl]oxy]phenyl](5,6-dihydro-1,4,2-dioxazin-3-yl)-, O-methyloxime)

as a drench or locally via syringe. Before selecting a fungicide, the basidiomycete fungus should be accurately identified. See *Fungicidal suppression of fairy rings* below.

Mask the symptoms or signs: (1) aerate the soil and drench it with a wetting agent to help retard the development of zones of dying and dead grass; (2) fertilizers can mask the appearance of the "stimulated zone" of dark green grass, use additional N (about 0.1 to 2.5 lb per 1000 square feet) in the area where rings occur to mask the dark green bands of turf; (3) if the fairy rings consists of only sporophores with no stimulated zone of green grass growth, rake off and dispose of the sporophores (wash hands and tools when finished).

Eradication

Dig out the fungal mycelium from the soil and remove it; this is more feasible for smaller-sized rings that are few in number. Remove and destroy the sod or kill it with a non-selective herbicide - do not compost it. A soil fumigant such as metam-sodium (Vapam) may be used to eradicate the residual fungal mycelium from the soil. It may be necessary to remove the soil to a depth of almost 3 feet, depending on the ring. The hole should be filled with clean or sterile soil or plant growth medium and re-seeded or re-sodded.

Fungicidal suppression of fairy rings

Fungicides may be used to suppress fairy rings before or after they become established, although the efficacy of the treatment may be poor and dependent upon the basidiomycete species, the turf, and the environment. It is difficult to eradicate severe fairy ring infestations with fungicides alone. The best course for most home owners is to mask the fairy ring symptoms with fertilizers, rather than by applying fungicides. High-value turfgrass installations will use fungicides routinely as preventive and curative measures. The fungicides vary in their efficacy, formulations and methods of application.

How to apply fungicides for fairy ring suppression

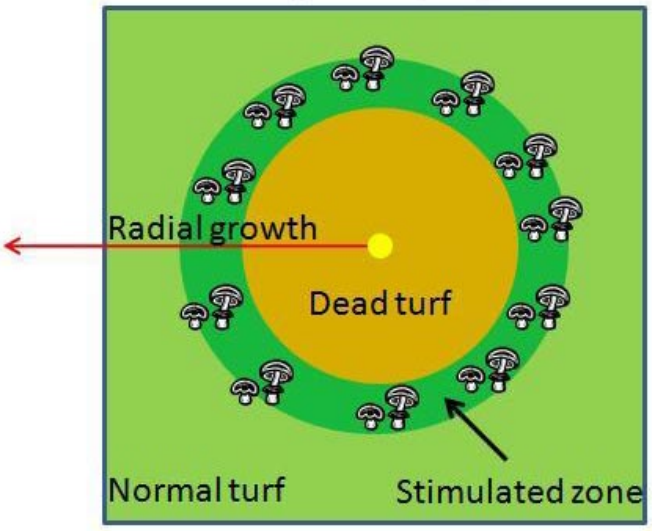
First, the entire diseased area should be aerated at least every 4 inches. In addition, an area extending about 2 feet out from the edge of the fairy ring should be aerated and treated with fungicide. After aeration, clean the equipment with appropriate sterilizing agent(s) to disinfest. Soak the aerated area with water by hand (containing a wetting agent).

As an example of a fungicidal treatment, the following text is excerpted from the PROSTAR 70WP (flutolanil) label. Flutolanil is regarded as the turf industry standard for suppressing most fairy rings. (Caution: label wordings may change; follow the instructions on the label of the product you are using.)

Preventative: "PROSTAR 70WP Fungicide, applied in 10–50 gallons of water at 2.2 oz. per 1000 square feet, may suppress the development of fairy ring caused by various basidiomycete pathogens. A second application may be made at a 21- to 28-day interval using the same dosage rate."

Curative: "PROSTAR 70WP Fungicide, applied in 10 to 50 gallons of water at 4.5 oz. per 1000 square feet, may suppress the development of fairy ring caused by various basidiomycete pathogens. Application should be made

to the affected area at the first sign of ring development (greening, death of turf, mushrooms). Symptom suppression may be temporary and symptoms may reoccur. In these cases, a second application at 4.5 oz. per 1000 square feet is suggested, not less than 30 days after the first application. Aerification prior to subsurface applications has been beneficial in some cases. Use of a nonionic surfactant in combination with PROSTAR 70WP is recommended. Treated areas should be irrigated prior to and after application with sufficient water to maintain growth of turf. Disease control is improved if turf is maintained at optimum fertility levels after symptom development. Turf that has been damaged extensively by fairy ring development may have to be reseeded. Do not treat more than 10,000 square feet per acre of turf area."



1. Fairy ring schematic (Type I ring)
2. Variation in a Type 1 fairy ring (below)

Fairy ring classification

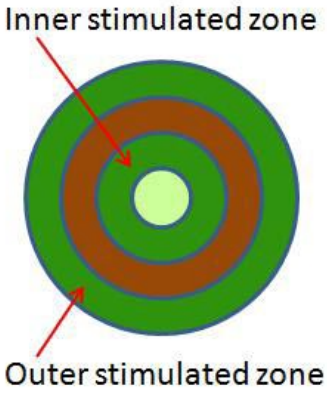
Fairy rings have been and are classified arbitrarily on the basis of various criteria. Such classification schemes provide useful models for understanding the dynamics of fairy rings.

Classification on the basis of damage caused to surrounding plants

Fairy rings can cause varying levels of damage to associated plant species, from great damage to no damage. Three scenarios are possible:

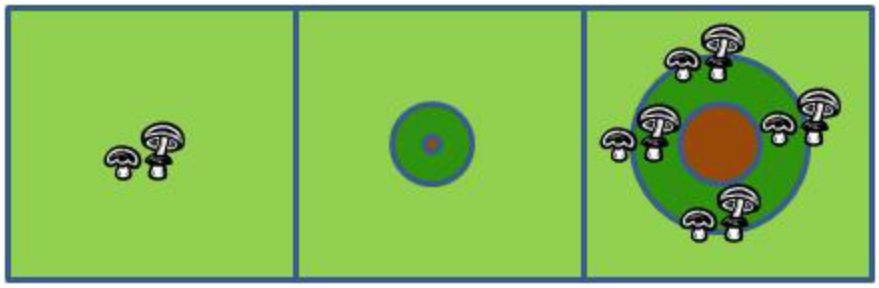
- Type I fairy ring: grass is killed or badly damaged.
- Type II fairy ring: grass is stimulated but not damaged.
- Type III fairy ring: grass or surrounding flora is apparently unaffected (only fungal sporophores are present).

Type I ring. A basiodiomycete fungus becomes established in the turf, either in non-living organic matter in the thatch layer on in the soil beneath the turf (indicated in diagram 1 by the yellow spot). As the food supply for the fungus becomes scarce, it begins to grow outward, radially in all directions (indicated by the red line), in search of other non-living sources of nutrition. Eventually, so much fungal mycelium forms in the soil that the soil becomes hydrophobic and repels water. This contributes to plant death by drought at the center of the expanding fairy ring (indicated by the brownish circle in the diagram). The fungal mycelium also dies this region as the ring expands. The decomposition of organic matter by the fairy-ring fungus creates ammonium, which in turn is converted to nitrates in the soil. The nitrates feed the grass at the edge of the ring, creating lush, dense, dark green ring of turf. In this area, sporophores of the associated basidiomycete form when soils become very moist for a prolonged period of time.



Some Type I fairy rings have more than one zone of stimulated turf (diagram 2). Outer and inner zones of stimulated turf are separated by rings of dead or dying grass (indicated by the brown color in the diagram).

In the development (etiology) of a fairy ring (diagram 3, next page), basidiospores or mycelial fragments are dispersed by wind, water, or soil, or on tools and equipment. Basidiospores or mycelial fragments land in thatch or soil containing the appropriate type of organic matter for a food supply (decaying wood or grass clippings). The basidiospore(s) or hyphal fragment(s) germinate within the thatch or soil and begin to grow outward in all directions. The fungus withdraws nutrients from the organic matter in the soil. The fungal mycelium spreads throughout the thatch or soil layer, up to 12 inches deep



3. Etiology of a Type I fairy ring Diagrams: Scot Nelson

in some soils. The first evidence of infection is the presence of a small cluster of mushrooms or a band or tuft of dark green grass (left, center). The ring or band of green grass results from the nitrogen that becomes available as the fungus decomposes the organic matter in the thatch or soil. A central area or spot or ring of dead grass may develop, caused by a loss of soil moisture from the area of fungal concentration (center). In the hydrophobic layer of dead grass and contaminated soil is a thick growth of fungal mycelium. Sexual reproduction occurs and mushrooms or other sporophores form at the periphery of the rings during periods of favorable conditions (rainy weather or intensive irrigation). The basidiospores are borne in the gills of mushrooms. The fungi survive as spores and mycelial fragments in or on organic debris, and as pathogens of woody plants (roots, stems).

Classification on the basis of the setting / host-fungus combination

Possible setting classes are (1) high-value turfgrass (golf courses, resorts, campuses, commercial buildings, parks); (2) residential or average-value landscapes; (3) natural forests, unmanaged or natural landscapes.

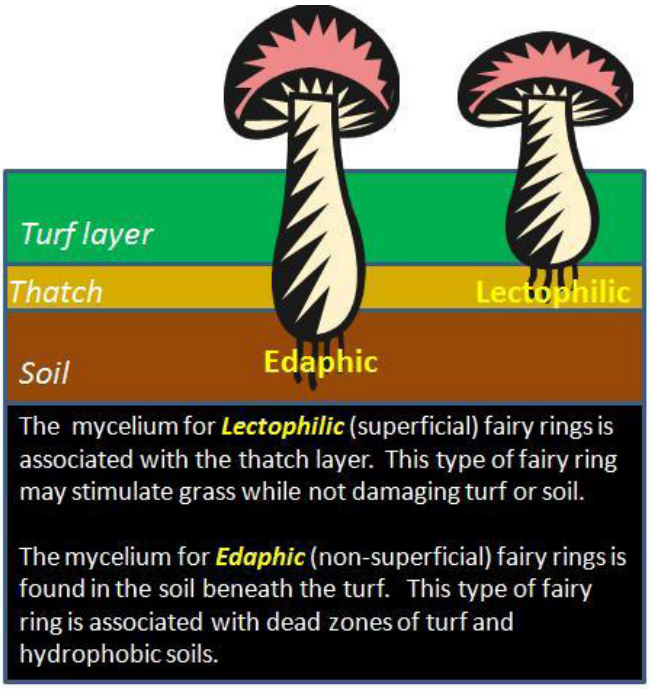
This type of classification can help guide decision-making related to management of fairy rings. Fairy rings of all types warrant management when they appear in high-value turfgrass settings due to their negative aesthetic impact. Type I fairy rings warrant management in residential settings due to their damage to turf. Fairy rings in residential or natural settings are a lower management priority.

Classification on the basis of the principle stratum of colonization (thatch vs. soil)

Fairy rings that feed on thatch are lectophilic; those that feed on soil organic matter are edaphic (diagram, right). Lectophilic fairy rings are more easily masked with applied fertilizers than edaphic fairy rings. Edaphic types pose a greater threat to plant health and may require more stringent management practices.

Classification on the basis of radial growth capability

"Tethered" fairy rings are associated with trees and are bound to their root systems. Their radial expansion is thereby limited to the radial diameter of the tree root system. "Free" fairy rings are not as restricted and can grow outwards indeterminately.



Photos: D. Hemmes, UH Hilo, Biology

Fairy ring examples from Hawai‘i

1. Type I “free” fairy ring, edpahic, in a residential setting: the green-spored parasol

Mushrooms (*Chlorophyllum molybdites*) mark the “stimulated zone” of turf growth (photo, above). Fairy ring fungi grow outward in the soil, radially from a central point of inoculation. The radial growth of the fungus in the soil creates the ring-like stimulated zone of green turf. The grass blades are longer and are darker green than the browner, dying turf within the ring. The outward growth of the ring is due to depletion of nutrients and the inhibitory effect on the fungus of the high concentration of soil ammonia that results from the decomposition of organic matter. As the fungus grows radially and the ring expands, additional sources of nitrogen for the grass become available in this stimulated zone. A band of turf greens up temporarily, only to succumb to the browning and possible death at a later date as the fungus continues its radial expansion. The inner area of the ring is hydrophobic. A mass of old fungal mycelium permeates the zone, causing it to repel water. Plants in the center of the ring die of drought because the soil is hydrophobic and repels water, and also dries out faster than it should.

2. Aseroe arachnoidea **on home lawn (Type II “free” fairy ring, lectophilic)**

A. arachnoidea, (above) the “starfish stinkhorn,” forming fairy rings on a lawn in Sunrise Ridge, Hawai‘i. The smell of the mature sporophores, similar to rotting meat, attracts flies, making a nuisance and allowing attachment of spores to the bodies of the flies, which subsequently disperse the spores to new locations to initiate new cycles of disease.

Stinkhorns are saprobic fungi found in areas that have been mulched with wood chips or where there is a natural or introduced supply of organic material or leaf debris. They may occur in flowerbeds, lawns, or other cultivated landscapes. They are associated with rotting stumps. They are found in the Hawaiian Islands, Africa, Oceania, and many other tropical locations.

Photos: S. Nelson

Photos: Don Hemmes, UH Hilo Biology

3. A puffball on seashore paspalum (Type II "free" fairy ring, lectophilic)

Above, the arrow marks the edge of a large fairy ring, the band-like "stimulated zone" on a golf course fairway in Hawai'i. Puffball-type fairy rings were abundant at this golf course. Here, the puffball *Vascellum floridanum* infests seashore paspalum (*Paspalum vaginatum*). Fairy rings often occur where buried wood exists in the landscape; perhaps old trees or tree parts were not removed from the area after bulldozing. In this situation, there is virtually no soil at, just a layer of volcanic cinders lies beneath the truf and the thatch is heavy in some spots. The close-up shows sporophores of the puffball retrieved from the stimulated zone of the fairy ring turf.

4. Type III "tethered" fairy rings

A dictyophora fairy ring (above) and (at top) mushroom photographer Taylor Lockwood sitting in the middle of a *Lepista subisabellina* fairy ring at MacKenzie Park on Hawai'i. Because they depend on the roots of a tree for nutrient supply, woodland fairy rings are referred to as "tethered" rings, whereas those in turf and for which the nutrient supply is spread though the soil or thatch are called "free" rings. This type of ring causes no particular damage to the landscape; it is not necessarily pathogenic to plants and may be beneficial, in the case of mycorrhizal fungi, which live in symbiotic relationship with trees and can form tethered rings.

References

Couch, H. B. 1962. Diseases of turfgrasses. Reinhold Publishing, N.Y. 289 p.

Dickinson, C.H. 1979. Fairy rings in Norfolk. Bulletin of the British Mycological Society.13: 91-94.

Hemmes, D. E., and Desjardin, D. E. 2002. Mushrooms of Hawaii. Ten Speed Press, Berkeley. 212 pp.

Latin, R.L. 2006. Turfgrass disease profiles: Fairy ring. Purdue University Cooperative Extension BP-113-W. http://www.ces.purdue.edu/extmedia/BP/BP-113-W.pdf.

Pataky, N. R. 1998. Fairy rings, mushrooms, and puffballs. University of Illinois Extension Report on Plant Disease RPD No. 403.

Pottorff, L.P. 2003. Fairy ring in turfgrass. Colorado State University Cooperative Extension. no. 2.908. http://www.ext.colostate.edu/PUBS/GARDEN/02908.html.

Settle, D., R. Kane, and L. Miller. 2006. Fairy ring suppression by preventive fungicide applications alone and with a wetting agent. http://cdga.org/pdf/FairyRing.pdf.

Swift, C. 1997. Fairy ring: A problem on turfgrass. Colorado State University Extension.

University of California Pest Management Guidline: Fairy rings. UC IPM Online, http://www.ipm.ucdavis.edu/PMG/r785100411.html.

Wong, G. Basidiomycete life cycle, http://www.botany.hawaii.edu/faculty/wong/Bot201/Basidiomycota/Basidiomycetes.htm; Mushroom life cycles, http://www.botany.hawaii.edu/faculty/wong/Bot201/Basidiomycota/Mushroom_Lifecycle.htm.

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